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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: Thorsten SCHUTTE, et al.

SERIAL NO.: NEW U.S. PCT APPLICATION

FILED: HEREWITH

INTERNATIONAL APPLICATION NO.: PCT/EP98/07729

INTERNATIONAL FILING DATE: 30 NOVEMBER 1998

FOR: TRANSFORMER

REQUEST FOR PRIORITY UNDER 35 U.S.C. 119 AND THE INTERNATIONAL CONVENTION

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In the matter of the above-identified application for patent, notice is hereby given that the applicant claims as priority:

COUNTRY	APPLICATION NO	DAY/MONTH/YEAR
GREAT BRITAIN	9725331.4	28 NOVEMBER 1997

Certified copies of the corresponding Convention application(s) were submitted to the International Bureau in PCT Application No. **PCT/EP98/07729.**

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The Patent Office

PCT/EP 98 / 07729

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The Patent Office
Concept House
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The Patent Office

Cardiff Road
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1. Your reference — 8368 /WBH

2. Patent application number *(The Patent Office will fill in this part)* — **9725331.4** — 28 NOV 1997

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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Patents ADP number *(if you know it)* — 40080740001

If the applicant is a corporate body, give the country/state of its incorporation — SWEDEN

4. Title of the invention — TRANSFORMER

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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Patents ADP number *(if you know it)* — 976001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   See note (d))

yes

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TRANSFORMER

The present invention relates to a transformer comprising at least one high voltage winding and one low voltage winding.

The invention is particularly applicable to power transformers having rated outputs from a few hundred kVA to more than 1000 MVA and rated voltages from 3-4 kV to very high transmission voltages, e.g. from 400-800 kV or higher.

Conventional power transformers are described in e.g. A.C.Franklin and D.P.Franklin, "The J & P Transformer Book, A Practical Technology of the Power Transformer", published by Butterworths, 11th edition, 1990. Problems related to internal electric insulation and related topics are discussed in e.g. H.P.Moser, "Transformerboard, Die Verwendung von Transformerboard in Grossleistungstransformatoren", published by H.Weidman AG, Rapperswil mit Gesamtherstellung: Birkhäuser AG, Basle, Switzerland.

In transmission and distribution of electric energy transformers are exclusively used for enabling exchange of electric energy between two or more electric systems. Transformers are available for powers from the 1 VA region to the 1000 MVA region and for voltages up to the highest transmission voltages used today.

Conventional power transformers comprise a transformer core, often formed of laminated commonly oriented sheet, normally of silicon iron. The core is formed of a number of legs connected by yokes which together form one or more core windows. Transformers having such a core are usually called core transformers. A number of windings are provided around the core legs. In power transformers these windings are almost always arranged in a concentric configuration and distributed along the length of the core leg.

Whilst the casings 6 and 8 are described as "semi-conducting" they are in practice formed from a base polymer mixed with carbon black or metallic particles and have a resistivity of between 1 and 10^5 Ωcm, preferably between 10 and 500 Ωcm. Suitable base polymers for the casings 6 and 8 (and for the insulating layer 7) include ethylene vinyl acetate copolymer/nitrile rubber, butyl grafted polythene, ethylene butyl acrylate copolymer, ethylene ethyl acrylate copolymer, ethylene propene rubber, and polyethylenes of low density.

The inner semiconducting casing 6 is rigidly connected to the insulating layer 7 over the entire interface therebetween. Similarly, the outer semiconducting casing 8 is rigidly connected to the insulating layer 7 over the entire interface therebetween. The casings 6 and 8 and the layer 7 form a solid insulation system and are conveniently extruded together around the wire strands 5.

Whilst the conductivity of the inner semiconducting casing 6 is lower than that of the electrically conductive wire strands 5, it is still sufficient to equalise the potential over its surface. Accordingly, the electric field is distributed uniformly around the circumference of the insulating layer 7 and the risk of localised field enhancement and partial discharge is minimised.

The potential at the outer semiconducting casing 8, which is conveniently at zero or ground or some other controlled potential, is equalised at this value by the conductivity of the casing. At the same time, the semi-conducting casing 8 has sufficient resistivity to enclose the electric field. In view of this resistivity, it is desirable to connect the conductive polymeric casing to ground, or some other controlled potential, at intervals therealong.

outer semiconducting casing thereof, the high and low voltage windings can be easily mixed in an arbitrary way for minimizing the short circuit forces. It is also possible to reduce the distributed inductance and design the transformer core for the optimum match between window size and core mass.

According to an embodiment of the invention at least some of the turns of the low voltage winding are each split into a number of subturns connected in parallel for reducing the difference between the number of high voltage winding turns and the total number of low voltage winding turns to make the mixing of high voltage winding turns and low voltage winding turns as uniform as possible. Preferably, each turn of the low voltage winding is split into such a number of subturns, connected in parallel, such that the total number of low voltage winding turns is equal to the number of high voltage winding turns. High voltage and low voltage winding turns can then be mixed in a uniform manner such that the magnetic field generated by the low voltage winding turns substantially cancels the magnetic field from high voltage winding turns.

According to another advantageous embodiment, the turns of the high voltage winding and the turns of the low voltage winding are arranged symmetrically in a chessboard pattern, as seen in cross-section through the windings. This is an optimum arrangement for obtaining an efficient mutual cancellation of magnetic fields from the low and high voltage windings and thus an optimum arrangement for reducing the short circuit forces of the coils.

According to still another advantageous embodiment, at least two adjacent layers have substantially equal thermal expansion coefficients. In this way thermal damages to the winding is avoided.

Cancellation of short circuit forces can be improved even further by splitting the turns of the low voltage winding into a number of subturns connected in parallel, preferably such that the total number of low voltage turns becomes equal to the number of high voltage winding turns. Thus, if the transformation ratio amounts to e.g. 1:3 each turn of the low voltage winding is split into three subturns. It is then possible to mix the low and high voltage windings in a more uniform pattern. An optimum arrangement of the windings is shown in Figure 4, where low and high voltage winding turns 30 and 32 respectively are arranged symmetrically in a chessboard pattern. In this embodiment the magnetic fields from each turn of the low and high voltage windings 30, 32 substantially cancel each other and short circuit forces are almost completely cancelled.

When splitting a winding turn into a number of subturns the conducting area of each subturn can be reduced correspondingly since the sum of the current intensities in the subturns remains equal to the current intensity in the original winding turn. Thus no more conducting material, (normally copper), is needed when splitting the winding turns, provided that other conditions are unchanged.

Figure 5 schematically shows how the transformer of the invention can be wound. A first drum 40 carries a high voltage conductor 42 and a second drum 44 carries a low voltage conductor 46. The conductors 42, 46 are unwound from the drums 46, 44 and wound onto a transformer drum 48, all three drums 40, 44, 48 rotating simultaneously. Thus the high and low voltage conductors can easily be intermixed. Joints can be provided between different winding layers.

In the transformer of the invention the magnetic energy and hence the stray magnetic field in the windings is reduced. A wide range of impedances can be chosen.

CLAIMS

1. A transformer comprising at least one high voltage winding and one low voltage winding, **characterised in** that each of said windings comprises a flexible conductor having electric field containing means but which is magnetically permeable and in that the windings are intermixed such that turns of the high voltage winding are mixed with turns of the low voltage winding.

2. A transformer according to claim 1, **characterised in** that said low voltage winding is wound as a low voltage winding layer positioned between two corresponding adjacent high voltage winding layers.

3. A transformer according to claim 1 or 2, **characterised in** that said windings are arranged in a repeated periodic pattern of one high voltage winding layer, followed by a low voltage winding layer, followed by two high voltage winding layers, followed by a low voltage winding layer, followed by two high voltage winding layers, etc.

4. A transformer according to any one of claims 1 to 3, **characterised in** that each one of at least some of the turns of the low voltage winding is split into a number of subturns connected in parallel for reducing the difference between the number of high voltage winding turns and the total number of low voltage winding turns.

5. A transformer according to claim 4, **characterised in** that each turn of the low voltage winding is split into a number of parallel-connected subturns equal to the number of high voltage winding turns.

6. A transformer according to claim 5, **characterised in** that the turns of the high voltage winding and the turns in the low voltage winding are arranged symmetrically in a

14. A transformer according to any one of claims 7 to 13, **characterised in** that each of said three layers is fixedly connected to the adjacent layers along substantially the whole connecting surface.

15. A transformer according to any one of claims 7 to 14, **characterised in** that the conductor also comprises a metal shield and a sheath.

16. A transformer according to any one of claims 7 to 15, **characterised in** that the cross-section area of the central conductive means is from 80 to 3000 mm^2.

17. A transformer according to any one of the preceding claims, **characterised in** that the external diameter of the conductor is from 20 to 250 mm.

18. A transformer according to any one of the preceding claims, **characterised in** that struts (27) of laminated magnetic material are located between the windings.

19. A transformer according to any one of the preceding claims, **characterised in** that the electric field containing means is designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72.5 kV up to very high transmission voltages, such as 400 kV to 800 kV or higher.

20. A transformer according to any one of the preceding claims, **characterised in** that the electric field containing meansis designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA and up to 1000 MVA.

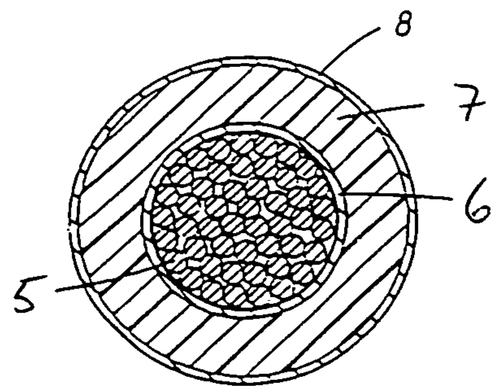
21. A method of winding a transformer, comprising simultaneously winding high voltage and low voltage flexible conductors having electric field containing means but which are magnetically permeable, such that turns of the high

ABSTRACT

A power transformer comprising at least one high voltage winding (32) and one low voltage winding (30). Each of the windings includes at least one current-carrying conductor, a first layer having semi-conducting properties provided around said conductor, a solid insulating layer provided around said first layer, and a second layer having semi-conducting properties provided around said insulating layer. The windings are intermixed such that turns of the high voltage winding are mixed with turns of the low voltage winding.

Figure 4.

Fig. 1



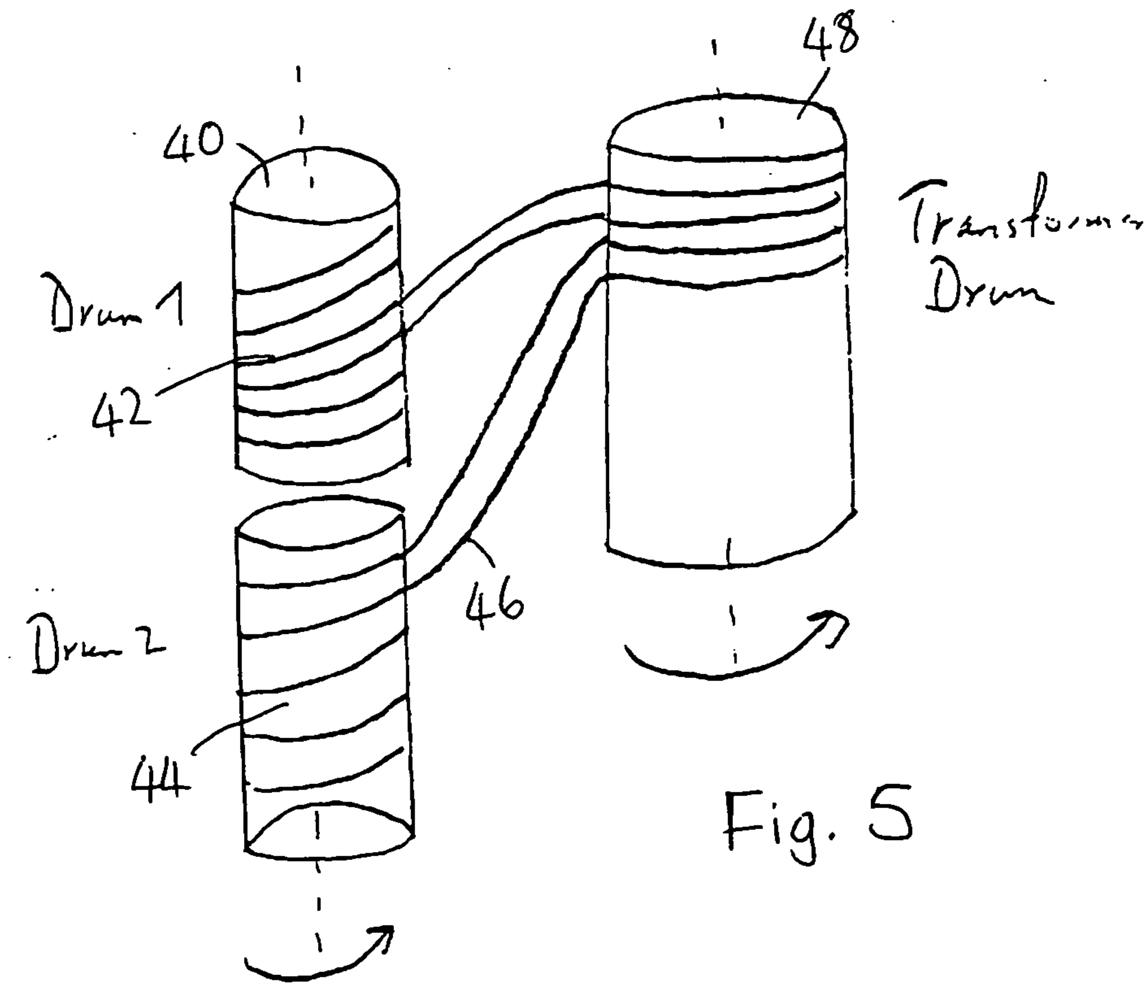


Fig. 5

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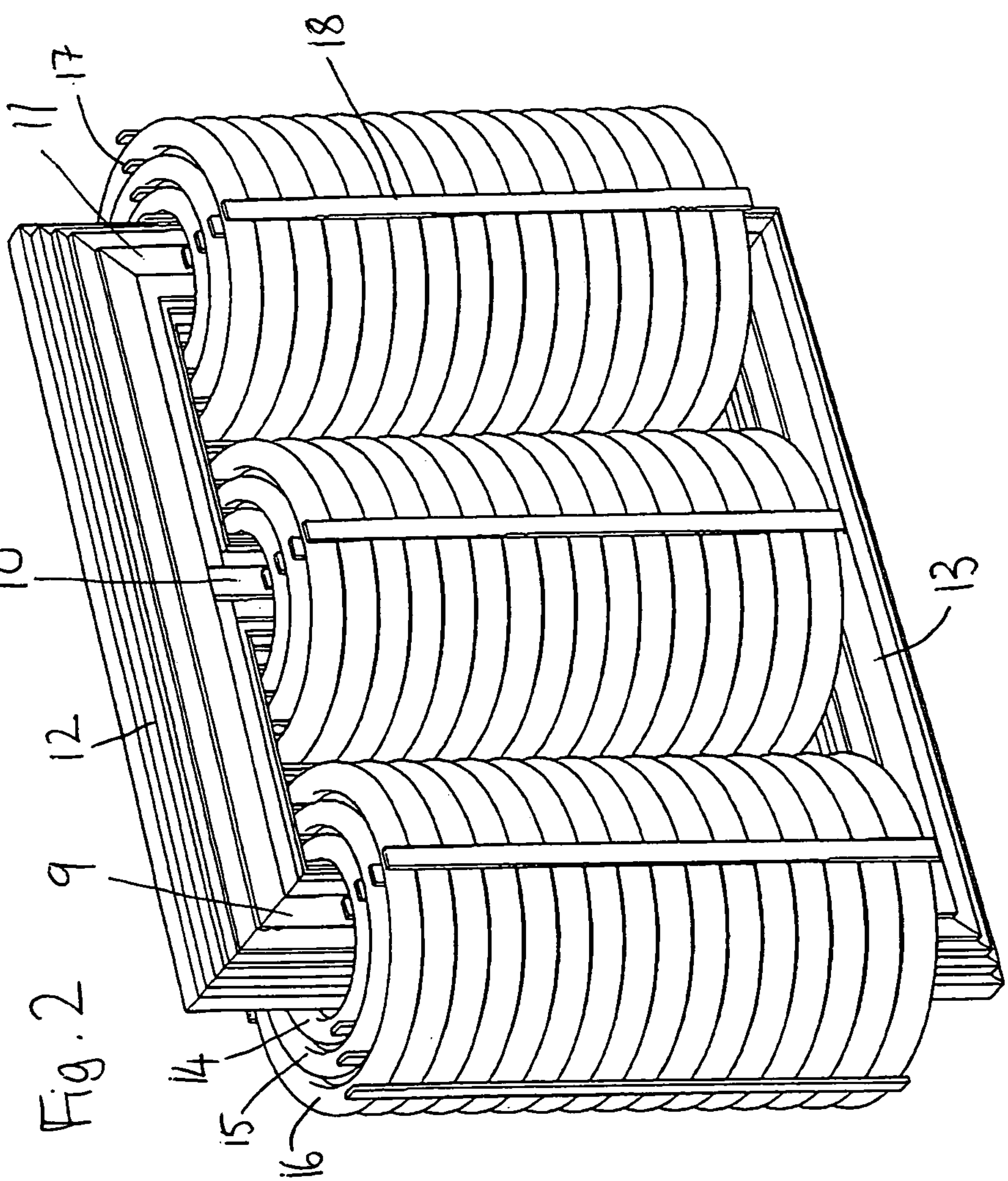
Fig. 2



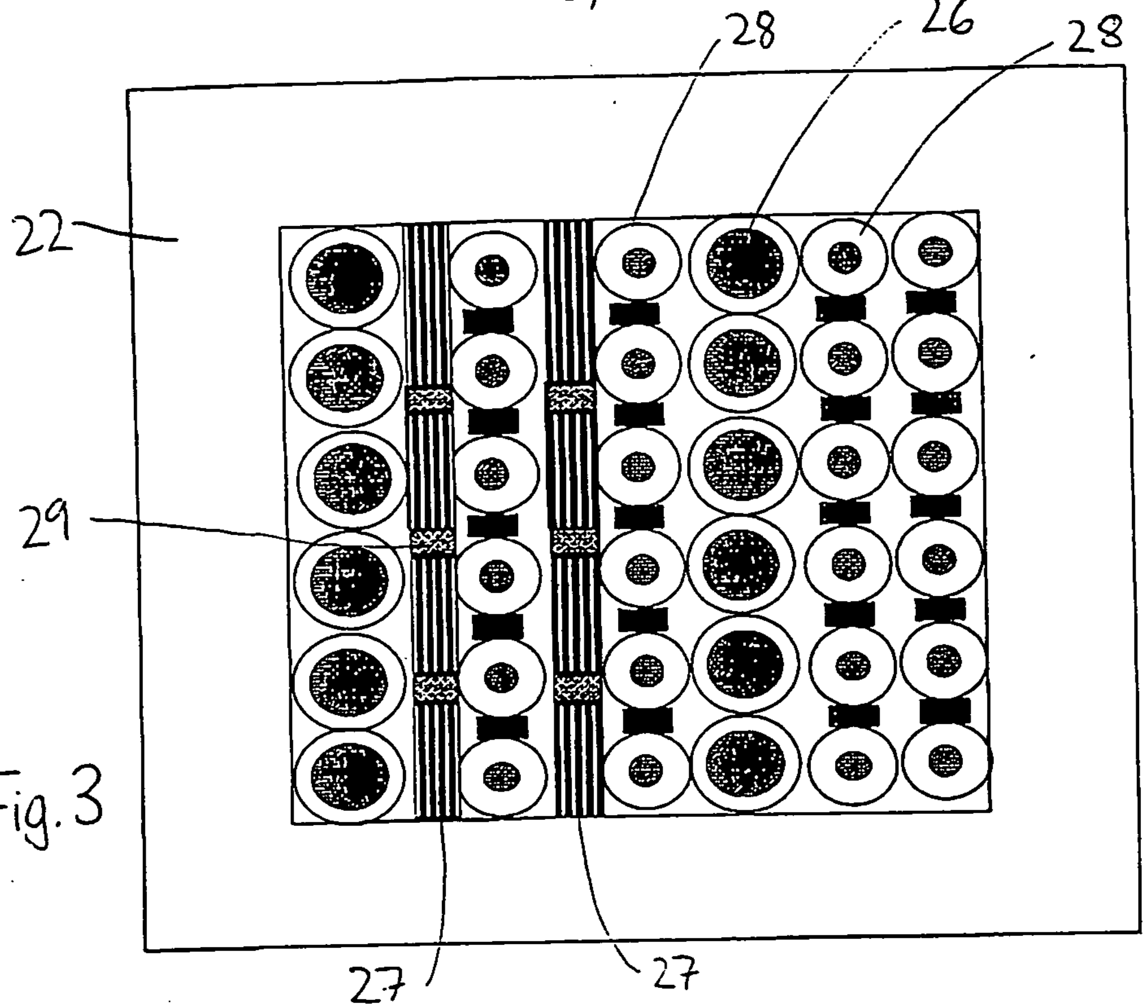


Fig. 3

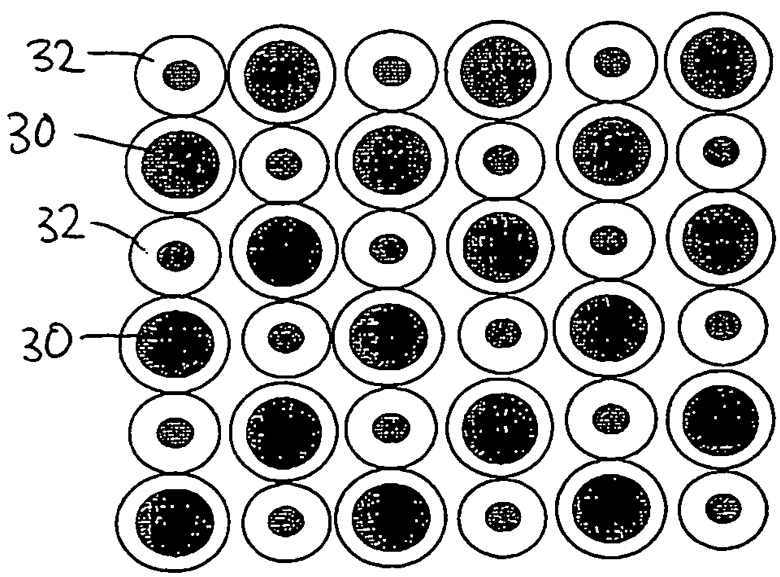


Fig. 4